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## V382 Vel: a “shocking” supersoft x-ray source?

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### **Abstract.**

Nova Vel 1999 (V382 Vel) was observed with BeppoSAX twice, 15 days and 6 months after the optical maximum. A hard X-ray source was detected in the first observation, while the second time also a very luminous supersoft X-ray source was detected. The continuum observed in the supersoft range with the BeppoSAX LECS cannot be fitted with atmospheric models of hot hydrogen burning white dwarfs. We suggest that we are observing instead mainly a “pseudocontinuum”, namely a blend of very strong emission lines in the supersoft X-ray range.

### **1. Introduction**

Nova Velorum 1999 (V382 Vel) was the second brightest nova of this half of the century ( $V=2.6$ ) (Seargent & Pearce, 1999). It was a Ne-O-Mg nova, and quite a “fast” one, with  $v \simeq 4000$  Km/s,  $t_2 = 6$  d,  $t_3 = 10$  d (Della Valle et al. 1999, Shore et al. 1999).

Two mechanisms of X-ray emission are known for classical novae in outburst: they teach us about the mass ejection process and about the final outcome of these systems (see Kahabka et al. 1999 and references therein). “Hard” X-ray emission (thermal bremsstrahlung continuum at plasma temperatures in the range 0.5-10 KeV, and possibly additional emission lines) with luminosities  $10^{33-34}$  erg s $^{-1}$  has been observed and attributed to *shocks*. The nova outburst is normally due to a radiation pressure driven wind and not to a shock wave, however shocks would be produced in interacting winds or interaction between the ejecta and the circumstellar medium. Luminous “supersoft” X-ray emission (luminosity of the order  $10^{27-38}$  erg s $^{-1}$ ) has also been observed and attributed instead to residual hydrogen burning in a shell on the white dwarf remnant. We expect to detect in this case an atmospheric continuum at  $T_{eff}=20-80$  eV and absorption edges of the white dwarf (or *emission edges* if the effective temperature is very high).

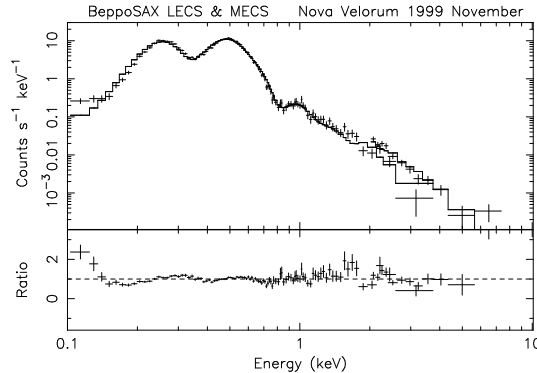


Figure 1. Spectra observed in the 0.1-10 keV range with the BeppoSAX LECS and MECS in November 1999 and best fit with a model atmosphere studied by Hartmann & Heise (1997). The fit is not acceptable in the supersoft range where most of the flux is detected. The lower panel shows the residuals in counts per energy bin.

## 2. The BeppoSAX observations

V382 Vel was observed for the first time with BeppoSAX 15 days after the optical maximum, on 1999 June 7-8 for 42.5 Ks with the two MECS, for 13.5 Ks with the LECS, for 23.3 Ks with the PDS. No other classical nova had ever been observed immediately after outburst and in such a broad energy range. The nova was then observed a second time on 1999 November 23 for 25.9 Ks with the MECS, 12.4 Ks with the LECS, 12.4 Ks with the PDS. In the June 1999 observation the nova was detected with a count rate  $0.1537 \pm 0.0020$  cts s<sup>-1</sup> and  $0.0620 \pm 0.0026$  cts s<sup>-1</sup> in the MECS and LECS, respectively (Orio et al. 1999a). At higher energies the  $2\sigma$  upper limits obtained with the PDS were 0.048 cts s<sup>-1</sup> in the 15-30 keV band and 0.074 cts s<sup>-1</sup> in the 15-60 keV band. The results are described in detail in Orio et al. 2000a and b. The spectrum was characterized by a very large absorption of the ejecta, which also shielded the central source. The best fit to the data is obtained with a VMEKAL model of thermal plasma with  $kT=6.2$  keV, flux  $F_x=1.8 \times 10^{-11}$  erg cm<sup>-2</sup> s<sup>-1</sup> (corresponding to an *unabsorbed* flux  $4.3 \times 10^{-11}$  erg cm<sup>-2</sup> s<sup>-1</sup>),  $N(H)=1.7 \times 10^{23}$  cm<sup>-2</sup>, and reduced iron abundance (Orio et al. 2000b).

## 3. The second BeppoSAX observation

In the second BeppoSAX observation, which we want to discuss more in detail in this paper, the count rate measured with the LECS was extremely high,  $3.468 \pm 0.003$  cts s<sup>-1</sup>, due to the emergence of the supersoft X-ray source (Orio et al. 1999b). The MECS count rate had instead decreased to  $0.0449 \pm 0.0015$  cts s<sup>-1</sup> (more than a factor 3 lower than in June). Again, there was no PDS detection with  $2\sigma$  upper limit was 0.080 cts s<sup>-1</sup> in the 15-50 keV range. The portion of the LECS spectrum *above* 0.8 keV can be fitted simultaneously with the MECS spectrum with a MEKAL model of thermal plasma with parameters:  $N(H) \simeq 2 \times 10^{21}$  cm<sup>-2</sup>,  $kT \simeq 700$  eV, unabsorbed flux  $\simeq 10^{-12}$  erg cm<sup>-2</sup> s<sup>-1</sup> (the

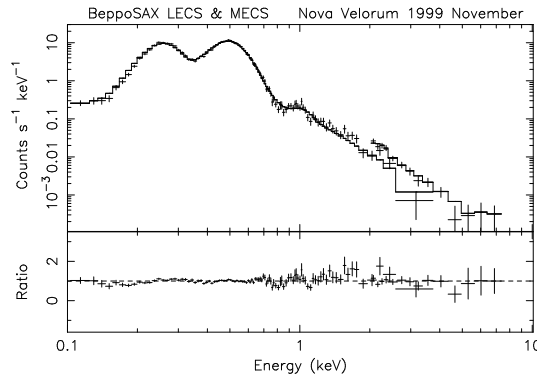


Figure 2. Here we fitted the LECS and MECS spectra, observed in November 1999 in the 0.1 to 10 keV range, with continuum and emission lines in the supersoft range (see text).

reduced  $\chi^2$  is 1.5). We tried to fit instead the LECS spectrum *below* 0.8 keV (where most of the flux is detected) with *a)* a blackbody, *b)* a blackbody with absorption edges, and *c)* with a more detailed model atmosphere (Hartmann & Heise 1997). 1999 and references therein). We found that a reasonable fit cannot be obtained with of these models. In Fig. 1 we show as an example the fit with *c)*, a model atmosphere studied by Hartmann & Heise (1997), with  $\log(g)=8.0$ , blackbody temperature 47 eV, and  $kT=0.9$  keV for a bremsstrahlung component at higher energy. This fit is not acceptable.

In Fig. 2 we fitted instead the whole LECS and MECS spectrum, from 0.1 to 10 keV, with continuum+lines. Only narrow emission lines, that can be produced in the nebula but not in the white dwarf atmosphere, make the fit possible. We obtain a much more acceptable fit than with any atmospheric model (reduced  $\chi^2=1.9$ ). In this example we obtained  $N(H)=2 \times 10^{21} \text{ cm}^{-2}$  (very close to the interstellar value). To explore some possible “complexity”, we assumed that the continuum is due to the Wien tail of a a blackbody-like component with  $kT \simeq 20$  eV, to a bremsstrahlung component at  $kT=47$  eV and an additional powerlaw component with photon index 4.9. The following, narrow emission lines were overimposed: N VII at 500.36 eV, O VII at 561.04 keV, Ne X at 1.022 keV, Si XV at 2.01 keV, FeXV at 6.67 keV. The acceptable fit is obtained by adding the emission lines and the quality of the result is not very dependent on the continuum assumed in the supersoft range. The lines of N VII, O VII, and Ne X were indeed observed shortly later with the CHANDRA LETG (on December 30 2000: courtesy of S. Starrfield et al., 2000). It is our understanding from preliminary results, however, that the continuum detected with the LETG and attributed to the central source was not sufficiently hot to produce the lines by photoionization. We hypothesize therefore that the emission lines were produced by shocks.

#### 4. Do supersoft X-ray observations of novae need to be revisited?

A low effective temperature ( $\leq 20$  eV) of the the post-nova white dwarf atmosphere might explain why a ionization nebula was been detected only in  $H\alpha$  for N Cyg 1992 (Casalegno et al. 2000) while *other ionization lines* (indicating a higher ionization potential) *were not present* in the nebula. We speculate therefore that also N Cyg 1992 (Krautter et al. 1996, Balman et al. 1998) might have been *cooler* than it appeared fitting the ROSAT PSPC spectrum. We remind that we came to the proposed possible explanation of the V382 Vel X-ray spectrum thanks to information on the CHANDRA data, obtained 6 weeks later by Starrfield et al. (2000). Both BeppoSAX and the ROSAT PSPC in fact could only detect a pseudo-continuum but *cannot resolve* the high ionization lines.

The difficulty in explaining the BeppoSAX spectrum without invoking the never-before predicted emission lines in the supersoft range (indeed observed shortly afterwards with CHANDRA), suggests that the observed “supersoft X-ray source” in V382 Vel is mostly due to non-resolved lines. The LECS must have detected a “pseudocontinuum” due to a blend of high ionization emission lines.

Very strong nebular emission lines in the supersoft X-ray energy range may indicate interesting possibilities. If “cool” continua with strong emission lines overimposed in the supersoft range are detected also for other novae (observed with Chandra or XMM in the future) we face new questions. Is it common to have powerful shocks in the nova wind even many months after the outburst? Should we consider instead a line driven wind in addition to the radiation driven wind to explain the nova mass loss? The nova theory is going to become more detailed and refined once the X-ray spectrum is known in detail for a statistically meaningful sample of objects. If the supersoft X-ray source in post-novae is generally “cooler” than it was believed, the fact that ROSAT detected very few post-nova-outburst white dwarfs is also explained (Orio et al. 2000c). The effective temperature must have been below the detectable range with the ROSAT PSPC.

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